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Research article

Effect of Stele type in the growth rotation of *Dalbergia melanoxylon*.

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Abstract

Examination of the effect of stele type in *Dalbergia melanoxylon* growth was conducted. Examination of stems to observe stele type and tissue water potential of Barreveld Faux, *Cupressus sempervirens* and *Dalbergia melanoxylon* was carried between 2nd – 23rd April 2015 at Mkwawa University Laboratories. About 120 stained stem sections were examined for stele type while other 120 stem pieces were incubated in Nacl solution for water potential. Forty (40) stained sections indicated ectophloic siphonostele in Barreveld Faux and *C. sempervirens* while 40 sections of *D. melanoxylon* indicated atactostele. Calculated water potential of Barreveld Faux was -0.01158597 bars and that of *C. sempervirens* was -0.01257201 bars while that of *D. melanoxylon* was -0.00320463 bars. Results found that, low water potential in *D. melanoxylon* is a factor for its slow growth rotation and this is due to the atactostele type existing in *D. melanoxylon*. A hard Blackwood and valued wood in *D. melanoxylon* is brought by this stele type. In order to initiate rapid growth rotation in *D. melanoxylon* is recommended to conduct genetic recombination of the *D. melanoxylon* with other species which have an easily growing wood although this can lower the hardwood quality and value of the *D. melanoxylon* wood.

Key words: *Dalbergia melanoxylon*, growth rotation, stele type, water potential, Barreveld Faux boxwood, *Cupressus sempervirense*

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1.0 Introduction

1.1 *Dalbergia melanoxylon* plant

Dalbergia melanoxylon is among species with highly valued wood, overharvested, poor native regeneration ability, low seed viability [1], slower growing rotation, forestry and non-domesticated flowering plant native to dry regions of Africa [2]. Due to its abundance in Africa before 1990s, has been nick-named as African blackwood, Zebrawood and African ebony but recently in 2000s has been classified as lower/risk near threatened in Tanzania, threatened in Kenya and extinct in Burkina Faso due to lack of propagation efforts against overharvesting and poor natural regeneration ability of the species [3]. Factors for poor seed viability, low germination percentage, low natural regeneration ability and rooting ability of *Dalbergia melanoxylon* has been recently investigated and the information published in various journals, this includes the first attempt in *D. melanoxylon* tissue culture ([4], [5], [6], [7], [8], [9]). Many research findings has reported the slow growth rotation in *Dalbergia melanoxylon* ([10], [11]) but there is no research finding reported on the factors contributing to the slow growth rotation, that is why this investigation opted to examine as to what extent do stele type and tissue water potential in *Dalbergial melanoxylon* contribute to slow growth rotation of the species.

1.2 Growth rotation of plants

Growth of plants from seedling stage to maturity and harvestable wood differs between different plant species. The growth differences are influenced by their anatomical structure differences which affect growth characteristics. Anatomy structures may influence the plant to grow faster or slow, to tolerate in drought and disease, to give higher yields or little. The period from seedling stage to harvestable wood as defined by this investigation is a growth rotation. Finding reports by ([12], [13], [14], [15], [10] and [11]) on *Dalbergia melanoxylon* growth rotation in natural environment is 70 to 100 years to attain a harvestable wood. This growth rotation is too long compared to other plant species while the mature *D. melanoxylon* wood is highly demanded for commercial timber than the period taken by the plant to attain a recommended wood [2].

1.3 Stele types in plants

In vascular plants, the stele is the central part of the root or the stem containing vascular tissues, ground tissues (pith) and pericycle all of them derived from procambium. Outside the stele lies the endodermis contained in the cortex [16], [17]. The earliest vascular plants had a stem with a hard central core (solid core of xylem) made of cylindrical strands of xylem and surrounded by a layer of phloem at the outside. The hard central core implies no pith (hollow cylinder of xylem) or opening at the xylem center. This stele arrangement was termed as protostele [16], [17]. With time as a result of adaptation in response to the environment, protosteles developed a region of ground tissues internal to xylem which was termed as pith or hollow cylinder of xylem. The ground tissues are vascular strand comprising a cylinder surrounding the pith. This stele arrangement was termed as siphonostele [16].

Today botanists have termed the protostele as primitive stele and siphonostele as advanced stele in the sense that physiological performance of vascular tissues with pith is higher and favor rapid growth and physiological activities in plants compared to vascular tissues without pith [18]. Siphonosteles today have variations depending on how the phloem system is arranged, the number of leaf gaps and the nature of vascular bundles. In some vascular plants the phloem is present only external to xylem (ectophloic siphonostele) or present in both external and internal to xylem (amphiphloic siphonostele) ([19]. Some vascular tissues contain no more than one leaf gap or non-overlapping leaf gaps in any transvers section (solenostele) while others contain multiple gaps in vascular cylinder in any one transvers section (dictyostele) [18]. The vascular plants in which the vascular bundles are arranged in one or two rings around the pith are termed as eustele while others have numerous scatted vascular bundles in the stem, these are termed as atactostele. Variations of vascular tissue arrangements among advanced plants (siphonostele) leads to variation in wood quality, wood hardness, water potential level as a result different ability to growth and different age to attain a harvestable wood (growth rotation) [18] this is why other plants can attain a harvestable wood at 10-20 years while *D. melanoxylon* attain a harvestable wood at 70-100 years [2] that is why was necessary to examine what is this type of stele in *D. melanoxylon*.

1.4 Plant water potential

Plant water potential can be defined as the ability of water to move from point A of the plant or cell to point B of the plant or cell within the plant due to free energy differences between the two points in the plan t[20]. Water moves from a region of high water potential to a region of low water potential. A process enables water to move from cell to cell along a water potential gradient from soil to root hairs to xylem to leaves [20]. The total water potential (Yw) in the plant tissue comprises of the osmotic water potential (Yo), pressure water potential (Yp), matrix water potential (Ym) and the potential due to gravitational force (Yg), Yw = Yo + Yp + Ym + Yg [20]. Matrix potential is the lowering of water potential due to adhesion of water molecules to other molecules on cell membrane. In most cases the matrix potential and potential due to gravitational force is small and can be ignored since a very small fraction of cellular water can be affected by these potential (Ym and Yg works out to be -0.1 bar per meter height). Thus for most purpose, water potential can be defined from the contribution of osmotic potential and pressure potential l[21].

1.5 Water potential and Plant growth

In accordance to [21] findings on plant water potential, Low water flow in plant cells in a given time leads to small cell size while plant cells with high water flow the cells become enraged. As a result of different cell size due to difference in water flow (water potential), enraged cell will grow higher compared to small sized cell in a given time except that rate of mycorrhizae reproduction in low water potential is higher than mycorrhizae reproduction in high water potential [22]. [23] reports indicated that reduced plant water potential induced by polyethylene glycol in hydroponics, inhibited growth and decreased the number of leaves per branch in the southern California droughtdeciduous species *Lotus scoparius* (Nutt. In T & G) Ottley. In other words, low water potential can be considered as a growth inhibiter and the high water potential is a growth promoter. For the plant to have low water flow in tissues (low water potential) or high water flow (high water potential) it depends on anatomy of the stele type (vascular tissues arrangement) it has and together stele type and water potential determine the growth rotation of a given plant species [18].

2.0 Material and methods

A total of 15 seedlings having age of 2 months from Barreveld Faux, *Cupressus sempervirens* and *D. melanoxylon* (5 seedlings each) were purchased from Tanzania Tree Seed Agency (TTSA) Morogoro and Transported to Biology Laboratory I at MUCE for water potential and vascular tissue (stele type) examinations. Procedures to conduct the intended examination started the next day from the day of purchasing the materials.

2.1 Water potential

A medium of Sodium chloride (Nacl) 10% was prepared enough to be used in 120 petri-dishes then 10mls of 10% Nacl was poured into each petri-dish. A 1cm piece was cut from soft stems of the 3 species (40 pieces for each species). Using Vernier callippers a length of each stem piece was recorded as an initial length W_1 for Barreveld Faux , W_2 for *Cupressus sempervirens* and W_3 for *D. melanoxylon*). Each stem piece was placed into a petri-dish and covered by petri-dish cover and incubated in the dark place for 24 hours to avoid light reaction to Nacl. Final length was recorded for each incubated stem after 24 hours and room temperature was recorded in the incubation period. A standard formula Yw = -RTC was used to calculate the water potential for each species,

where by:

Yw = water potential, R = Gas constant (8.3×10^{-3} kg MPa mol^{-1} k^{-1})

T = Absolute Temperature (T = 24^oC), C = Solute concentration (difference in water concentration. (molarity = mol/kg)

1. **1.** Water potential of W1 Barreveld Faux will be - {($8.3x10^{-3}$ kg)(24+273k)($4.7x10^{-3}$m)}

= - {(0.0083kg)(297k)(0.0047m) = -0.01158597 bars

2. **2.** Water potential for W2 Cupressus sempervirens will be - {($8.3x10^{-3}$ kg)(24+273k)($5.1x10^{-3}$m)} = - {(0.0083kg)(297k)(0.0051m) = -0.01257201 bars
3. **3.** Water potential for W3 *D. melanoxylon* will be {($8.3x10^{-3}$ kg)(24+273k)($1.3x10^{-3}$m)}

= - {(0.0083kg)(297k)(0.0013m)} = -0.00320463 bars

2.2 Stele type (vascular tissues)

About 40 fine and soft slices from each of the plant species were cut from the sampled seedlings and placed in petri-dishes containing distilled water. Soft papers were used to dry water from the petri-dish before staining process. Aniline sulphate, 50% glycerol, 100% glycerol and Methylene blue were used to stain the slices. Each petri-dish was covered by a cover slip and observed under a low power magnification before adjustment of magnification for fine view of the tissues. Photos from the observed tissues were taken for comparison to permanent slide tissues. (Barreveld Faux tissues were labeled as W1, W2 for *Cupressus sempervirens* and W3 for *D. melanoxylon*).

3.0 Results and discussion

3.1 Water potential

From the calculated water potential $-0.00320463 < -0.01257201 < -0.01158597$ it means that $W3<W2<W1$ (Figure 1) or *D. melanoxylon* water potential is the most smallest four times compared to *C. sempervirens* and Barreveld Faux water potential. In these results Barreveld Faux has the highest value of water potential and *C. sempervirens* is the second. Confidently, there is a significant difference between *D. melanoxylon* water potential and the remaining two species at $P < 0.05$. This is calculated from $(-0.01257201) - (-0.00320463) = 0.00936738 < 0.05$. The results indicate that since *C. sempervirens* is a higher woody plant like *D. melanoxylon* (Figure 7, 8 and 9) but its water potential is greater 4 times that of *D. melanoxylon* that means most of woody plants not all may have higher water potential several times compared to *D. melanoxylon*. The water potential value have a direct influence on the growth rotation that is why compared to most of higher woody plants, *D. melanoxylon* is mostly reported to have the lowest growth in the natural environment. Barreveld Faux plant has the highest water potential and reported as a faster growing plant [21] that is why is mostly used as a border plant (Figure 6).

3.2 Stele type (stem anatomy)

When the result photos compared to permanent slide tissues is shown that Barreveld Faux boxwood and *C. sempervirens* are dicotyledons woody plants while *D. melanoxylon* is a monocotyledons woody plant but all the three species have siphonostele vascular tissue but having variations within them (Figure 2, 3, 4 and 5). Barreveld Faux boxwood and *C. sempervirens* the phloem is present only external to xylem (ectophloic siphonostele) while *D. melanoxylon* have scatted vascular bundles (atactostele) in which the xylem is black, white phloem and stippled pith. Ectophloic siphonostele in *C. sempervirens* and Barreveld Faux seems to allow fast performance and fast growth in the given species. As a variation or modification, *D.*

melanoxylon black xylem dominates the stippled pith at the mature wood (Figure 9). Another exceptional feature in *D. melanoxylon* is that the hardening of the dominating black xylem is abnormal or extremely abnormal compared to most of higher woody plants and this may have limited normal growth of the species to the slow growth rotation.

The result findings of this research suggests that extremely hardening and compactness of the black xylem in *D. melanoxylon* is because the xylem is made of a lignified thin-walled parenchyma cells which are reported to form the bulk wood of the plant stems and reported to strengthen the plant stems as can be supported by [18] in anatomy of stems. A direct interpretation from anatomy of stems for the domination of the xylem on the stippled pith in *D. melanoxylon* is extremely higher water conduction in the stem at seedling stage before extremely hardening at mature stage of the stem. This leads to vulnerability *of D. melanoxylon* seedlings to available water [11], [2] while the mature *D. melanoxylon* plants are water demanding [14] due to hardened wood at that stage.

4.0 Conclusion and recommendation

The strongly hardening and compactness at mature stage of the xylem dominating the central part of the *D. melanoxylon* wood from the atactostele type of vascular tissue results into very low water potential of the species leading to very slow growth rotation attaining a harvestable wood at 70-100 years. This finding recommends a genetic recombination of the *D. melanoxylon* with the easily growing wood plants although this can lower the wood quality and value of the *D*. *melanoxylon* wood.

5.0 Acknowledgement

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8.0. Figures

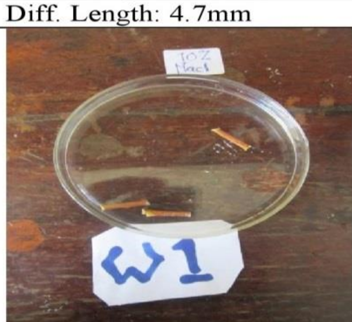
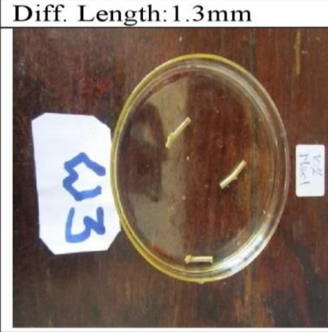
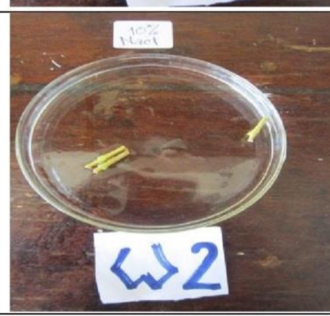
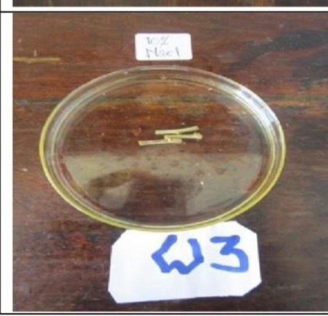
S.No	Specimen W1	Specimen W2	Specimen W3
1	Initial Length: 20.0mm	Initial Length:20.0mm	Initial Length:20.0mm
2	Final Length:24.7mm	Final Length:25.1mm	Final Length: 21.3mm
3	Diff. Length: 4.7mm	Diff. Length: 5.1mm	Diff. Length:1.3mm
4			
5			

Figure 1: Representative stems in petri-dish for water potential

Note: **W1=** Barreveld Faux Boxwood (Common name), **W2=** *Cupressus sempervirens*,

W3=*Dalbergia melanoxylon*

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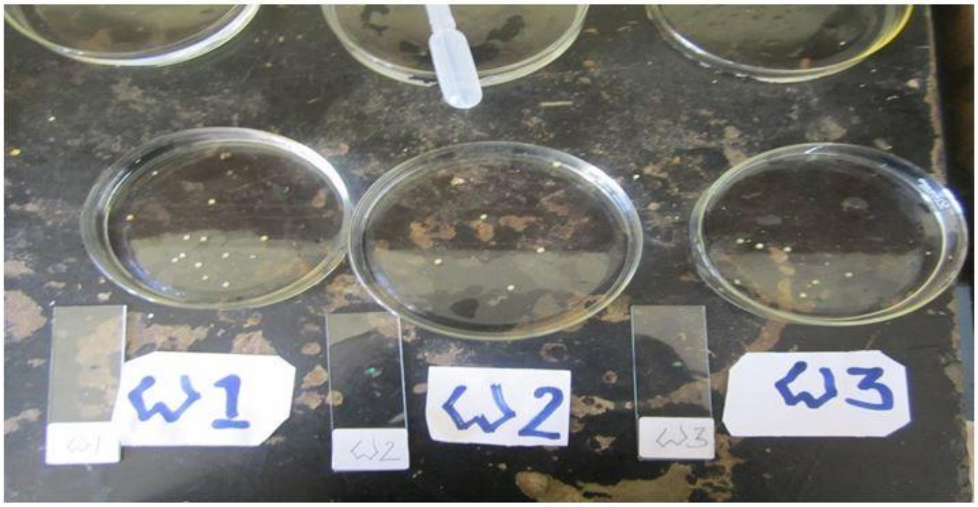

Figure 2: Representative stained tissue sections showing vascular tissue arrangement (stele type)

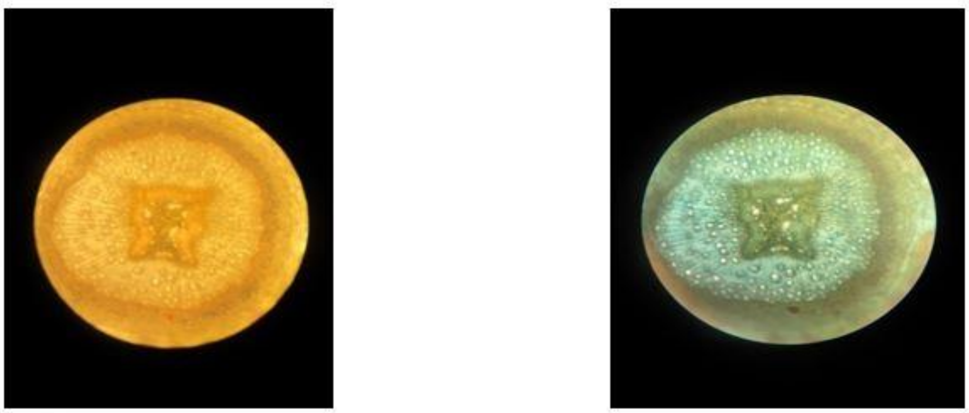

Figure 3:Vascular tissue arrangements in Barreveld Faux (W1)

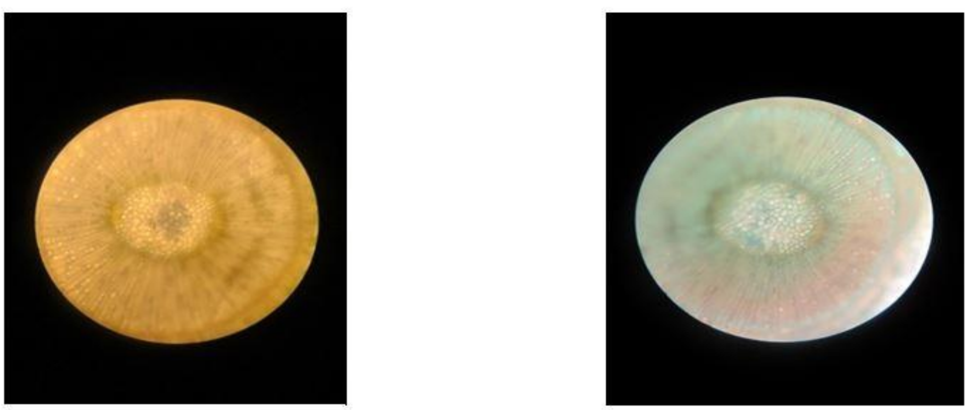

Figure 4: Vascular tissue arrangements in *Cupressus sempervirens* (W2)

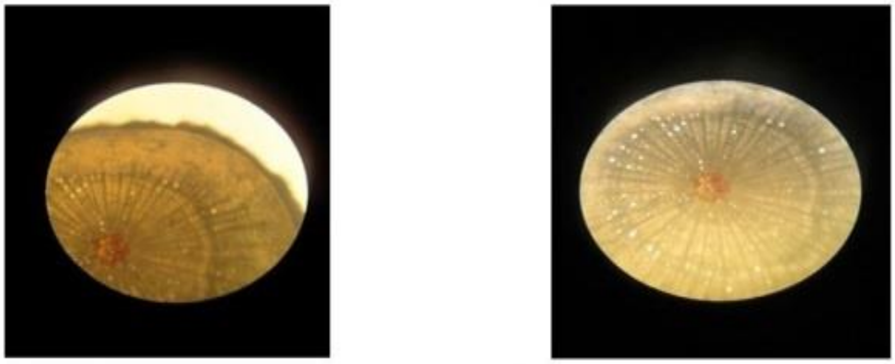

Figure 5: Vascular tissue arrangements in *D. melanoxylon* (W3)

Figure 6: Barreveld Faux Boxwood.

Figure 7: *Cupressues sempervirens* tree

Figure 8: *Dalbergial melanoxylon* tree.

Figure 9: Stele type in *Dalbergia melanoxylon* wood